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Evaluation of Plant Spacing for Different Morphological, Physiological and Biochemical Traits of *Sorghum bicolor* L

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ABSTRACT

Sorghum is cultivated for its vegetative portion and grains that are mainly utilized as animal feed as well as for human consumption. Sorghum grains are used in the formation of beer and gluten feed. Agriculture is the major source of subsistence of people living in rural areas and a major contributor to the economy of the country. Standardization of Agronomic procedures for getting high output is always desirable for researchers. The present study was conducted to evaluate the grain yield and quality of sorghum varieties under different plant spacing. Two sorghum varieties YS-98 and YS-16 and four treatments of the plant to plant spacing (10, 15, 20 and 25cm) were used. Significant effects were observed between plant spacing and different plant parameters like the height of the plant, planting density, 1000 grain weight, plant weight, number of leaves and total grain production. YS-16 outclassed YS-98 in all characters except in Panicle Length and 1000 Grain Weight. In mean comparison plant spacing of about 25cm gave more favorable results as compared to other spacing treatments, this may be because the competition between plants was minimized when they were sown 25cm apart.

1. Introduction

Pakistan is present in the South-Asian Region. Its latitude is about 23º-37º in the north and the longitude is 61º-76º, while its total area is 79.65 million hectares (Oxford Atlas, 1998). Crops and livestock are playing a pivotal role in the economic growth of people living in rural areas. The livestock sector contributed about 11.8% to the national GDP of Pakistan during 2015-16. The population of livestock is about 186.20 million heads (Govt. of Pakistan, 2016). About 65 % population of country is involved in agriculture with the prospect of agribusiness. Globally, agriculture including livestock, is the main source of income for millions of people. The importance of livestock is increasing day by day and the livelihood of rural people mainly depends on Livestock (Reddy et al., 2003; Awika & Rooney, 2005; Shava & Masuku, 2019).

Sorghum (*Sorghum bicolor* L.) belongs to family Poaceae. It is locally called as Jawar and mostly used in making hay and silage. Sorghum is mainly grown for the dual purpose such as fodder as well as grain. In the world, there are many types of sorghum crop e.g. grass sorghum, sweet sorghum, grain sorghum and broomcorn sorghum. But the most common is sorghum bicolor species. The cost of production and nutritive value of grain sorghum and corn is almost the same while the environment is the most important component for the selection of the crop (Ayubet al., 2012; Zerbini & Thomas, 2003). Less amount of water is required for sorghum crop so it may replace the corn crop. It also gives more yield in a hot and dry climate as compared to the maize crop. Studies suggested that sorghum crop requires only twenty-three-acre inches water for good crop establishment (FAO, 2006).

Sorghum is usually grown during the summer season. Sorghum is a high yielding crop having more tolerance against abiotic stresses such as drought stress. Under scarcity of water sorghum rolls its leaves to control the water loss due to transpiration (Tari, 2013). Sorghum is a cash crop in the region of semi-arid plains. The grain of the sorghum has more protein content as compared to the protein content in maize. The tolerance capacity of the sorghum is better than the maize crop. Sorghum crop is sown in the tropical and sub-tropical regions of the world and needs fewer resources to grow (Taylor et al., 2006). Future demands of livestock and humans can potentially be fulfilled by sorghum crop as fodder and grain food respectively. Ethanol is syrup that is extracted from sweet sorghum. It is a rapidly growing crop relatively more tolerant to dryness, containing a high percentage of protein and has a high yield. It produces more seed and fodder in a short duration (Maunder, 2002; Amanullah et al., 2007). Its composition is 71% carbohydrates, 2% crude fiber, 11% protein and also contains minerals and extractable nitrogen (FAO, 2014). The sorghum grain contains more composition of starch that is slowly digestible as compared to other cereal crops. It also contains the phenolic compound like 3-

deoxyanthocyanidins (Morais et al., 2015). Plant density is an important factor which can determine the productivity of crop (Khaliq et al., 2009). The plant population in a specified area is very important for getting the maximum grain yield. Maintenance of the planting density in an area would make sorghum crop production more beneficial. Cultivation of plants with an accurate density has a positive effect on crop yield components, thus maximum yield will be achieved by the optimum plant population (Widdicombe & Thelen, 2002). However, the main problem to the farmer community is to the maintenance of the ideal planting population in a unit area. The number of plants in an area has a unique importance in the sense of agronomic prospect. It is involved in the manipulation of the environment of soil. It has an impact on the growth, development and the yield of the crops. If we are increasing the plant population in an area then there will be a loss of yield and also impact on the vegetative growth of the crop (Caliskan et al., 2007).

The ideal planting density for getting maximum yield from the crop depends on its genotype and location. In countries like the USA, the best high yielding density is about 30-50 plants in a meter square (Grichar, 2007). Low plant population of a crop results in high weeds density, poor absorption of sunlight and low yield, while on the other hand over plant population cause lodging of the plants, poor sunlight interception in the canopy of the plants, hence reducing photosynthesis process due to shading of lower leaves resulting in a significant reduction of production (Lemerle et al., 2006; Bishnoi et al., 1990). The Tillering process of sorghum is a very important morphological component for grain production because it has impacts on the process of light absorption, water use by the plant, grain yield production, competition between the adjacent plants and also influence other plants physiological and biological processes (Krishnareddy et al., 2006).

The sorghum digestibility remains to be related because of pronounced starch and protein interactions so advancement in sorghum crop digestibility is very important for its utilization and therefore, maximization of its nutritious advantages. There are different approaches except agronomic and genetics, that are used to increase the digestibility of sorghum. The approaches including baking process, extrusion, nixtamalization, pressure-cooking and flaking with and without reducing agents are used for reducing the moisture process techniques (Elkhalifa et al., 2006). The objective of the present research was to find out the suitable spacing distance to maintain the optimum plant population to gain maximum production.

2. Materials and Methods

This research was carried out to compare sorghum varieties and different plant spacings. The experiment was conducted during March 2018 at an agronomy farm, University of Agriculture, Faisalabad, Pakistan.

2.1. Design of Experiment

The design of experiment was a Randomized Complete Block Design (RCBD) with factorial arrangements. All the treatments were repeated three times and the net size of the plot was 3.6 meter × 2 meter. In experiment two factors variety and planting space were used.

2.2. Site of Experiment

The research was conducted at Agronomy Research Farm, University of Agriculture Faisalabad. The texture of the soil of the research area was sandy clay loam. The experimental crop was cultivated in the sub-tropical condition of Faisalabad. The experimental location of the area was 31° north latitude, 73° east longitudes and the altitude is 185 meters.

2.3. Soil analysis

The experimental soil was analyzed for the evaluation of the soil properties (Table 1). Soil sample for analysis was taken from 30 cm depth by using an auger. The sample of soil was analyzed for textural determination by the use of the Bouyoucos hydrometer method. The sand, silt and clay proportion of the soil was calculated by the use of sodium hexameta phosphate at the rate of one percent as dispersing agent.

Table 1. Physiochemical Properties of Experimental Area

Physiochemical properties	*Units*	*Analytical values*
EC	dSm^{-1}	1.02
Organic Matter	%	0.62
Nitrogen	%	0.04
Soil Texture	-	Sandy clay loam
Soil pH	-	7.7
Available P	Ppm	13.8
Available K	Ppm	135
Available Mo	Ppm	0.07

2.4. Crop husbandry

Two sorghum varieties (YS-98 and YS-16) were taken from the research institute i.e. Maize and Millet Research Institute, (MMRI) Yusafwala, Sahiwal. The crop was sown by hand drill method in lines on March 10, 2018 using the seedling rate of 25 Kg ha-1. After the emergence; the plant to plant spacing was maintained by thinning according to the respective treatments. Row to row distance was maintained at 60 cm in each treatment. Fertilizers were applied to the crop at the rate of 170 N: 85 P: 60 K: kg ha-1 by using urea (46% Nitrogen), diammonium phosphate (18% Nitrogen, 46% P2O5) and sulfate of potash (50% K2O).

The full dose of phosphorous, potash and one-third of the nitrogen was applied at the time of soil preparation. Remaining nitrogen was applied with first and second irrigation applications in equal splits. For the control of early emerging weed the herbicide Atlantis (iodo + mesosulfuron) at the rate of 14.4g ha-1) was applied. Four irrigations were given, first soaking irrigation was of 4 acre inches and the remaining each of irrigation was of 3 acres inches during the growth period of the crop.

All other agronomic practices were performed as recommended. Different parameters were recorded such as planting density (m-2), height of plant (cm), panicle-length (cm), internodal length (cm), flag-leaf area (cm2), weight of plant (g), plant stem thickness (cm), number of leaves/plant, 1000 grain weight (g), grain yield (kg ha-1), crude protein content (%), crude fiber content (%), total ash content (%) and brix (%).

2.5. Statistical Analysis

The statistical analyses of collected data were conducted by the use of statistical software using analysis of variance technique. All treatment means were compared using least significance difference (LSD) test at 5% probability level (Steel et al., 1997).

3. Results and discussion

Plant spacing was highly significant for plant density, plant height, panicle length, inter nodal length, flag leaf area, weight of plant, plant stem thickness, 1000 grain weight and grain yield. Varieties were also highly significant for all parameters except plant density which is non-significant (Table 2).

Table 2. ANOVA for agronomic parameters

Agronomic parameters	***Variable***	***Mean Square***	***F- Value***
Plant Density	Plant Spacing	98.5	137.9**
Plant Height	Variety	1.5	2.1^{NS}
	P*V	0.5	0.7 NS
	Plant Spacing	941.4	130.35**
	Variety	32340	4478.16**
	P*V	10.2	1.42^{NS}
Panicle Length	Plant Spacing	22.9028	38.57**
	Variety	28.1667	47.44**
	P*V	0.25	0.42NS
Inter Nodal Length	Plant Spacing	7.48	36.70**
	Variety	31.51	154.56**
	P*V	0.093	0.46^{NS}
Flag Leaf Area	Plant Spacing	88	31.73**
	Variety	104424	37570.3**
	P*V	9	3.14*
Weight of Plant	Plant Spacing	3733.2	153.57**
Plant Stem Thickness	Variety	69768.2	2869.9**
	P*V	37.2	1.53^{NS}
	Plant Spacing	3.75	5176.17**
	Variety	0.6	829.2**
	P*V	0.61	84.73**
Leaves Per Plant	Plant Spacing	2.37	5.05**
	Variety	57.04	121.30*
	P*V	0.04	0.09^{NS}
1000 Grain Weight	Plant Spacing	14.2392	10741.7^{**}
	Variety	19.584	14773.9^{**}
	P*V	0.2619	197.59^{**}
Grain Yield	Plant Spacing	893734	6824.39**
	Variety	6036927	46096.8**
	P*V	5007	38.23**

*P*V=Plant Spacing vs Variety*

***Highly Significant, *Significant, N.S-Non-Significant*

Maximum height of plant was obtained in variety YS-98 was 219.50 cm, and in variety YS-16 the maximum height of the plant was 290.67 cm was observed. Maximum panicle length in YS-98 was 41 cm and 38.83 cm in YS-16 when both these varieties were sown at the planting distance of 10 cm (Table 3).
If low distance is maintained then there will low interception of light due to entangled canopies of the plants. Andrade *et al*., (2002) noticed reduction in plant biomass production due to their close sowing whereas wider sown plants tend to have more panicle length and more per plant production as compared to closer sown plants (Miah et al., 1990). Moreover, plants grown closer to each other tends to grown up by increasing their height i.e. more inter nodal length and production of narrower leaves (Konuskan, 2000).

Moreover, plants grown closer to each other tends to grown up by increasing their height i.e. more inter nodal length and production of narrower leaves (Konuskan, 2000). Maximum inter nodal length was 13.16 cm in YS-98 and 15.33 cm in YS-16 at the planting distance of 10 cm. Maximum flag leaf area was observed 198.94 cm^2 in YS-98 and 333.7 cm^2 in YS-16 at the planting distance of 20 cm. Maximum weight of plant was observed 574.00 gin YS-98 and 682.67 gin YS-16 at the planting distance of 20 cm. Kashiwagi et al., (2006) noticed increase in stem thickness of the plants growing at more distance to each other than the closer ones. Maximum plant stem girth was observed 3.95 cm in YS-98 and 4.18 cm in YS-16 at the planting distance of 25 cm (Table 3). Maximum no. of leaves per plant was observed 15 in YS-98 and 17 in YS-16 at the planting distance of 20 and 25 cm. Maximum 1000 grain weight was observed 23.51 gin YS-98 and 24.94 gin YS-16 at the planting distance of 25 cm. Maximum grain yield was observed 3813.03 $kg.ha^{-1}$ in YS-98 and 4818.09 kg. ha^{-1} in YS-16 at the planting distance of 20 cm.

Table 3. Mean comparison for agronomic parameters

Agronomic parameters	*Variety*	*PS-1(10cm)*	*PS-2(15cm)*	*PS-3(20cm)*	*PS-4(25cm)*
Plant Density	Variety 1	15	10	8	5
	Variety2	15	11	8	6
Plant Height	Variety 1	219.5	211.67	198.17	190.17
	Variety2	290.67	286.33	269.5	264.67
Panicle Length	Variety 1	41	39.83	38.66	36.33
	Variety2	38.83	37.16	37	34.16
Inter Nodal Length	Variety 1	13.16	12.16	11	10.5
	Variety2	15.33	14.33	13.16	13.16
Flag Leaf Area	Variety 1	192.09	196.08	198.94	196.27
	Variety2	322.13	325.88	333.7	329.37
Weight of Plant	Variety 1	519.33	542	574	556.67
	Variety2	622	647.67	682.67	671
Plant Stem Thickness	Variety 1	2.12	2.61	3.72	3.95
	Variety2	2.72	2.91	3.84	4.18
Leaves Per Plant	Variety 1	13.33	14	14.66	14.66
	Variety2	16.33	17.33	17.66	17.66
1000 Grain Weight	Variety 1	22.02	20.92	23.35	23.51
	Variety2	22.34	22.9	24.85	24.94
Grain Yield	Variety 1	3320.4	3151.9	3813.3	2876
	Variety2	4311.4	4089.5	4818.09	3953.08

LSD ($p \leq 0.05$)

Fernandez et al., (2012) observed increase in grain yield as well as in 1000 grain weight with more spacing between the plants. Similarly more plant spacing reduce the competition between the plants and sources are efficiently utilized by plants for production of various biochemical compounds (Rutto et al., 2013). Maximum crude protein content percentage was observed 9.35 in YS-98 and 9.61 in YS-16 at the planting distance of 25 cm. Maximum crude fiber content percentage was observed 32.40 in YS-98 and 32.61 in YS-16 at the planting distance of 25 cm. Maximum total ash percentage was observed 8.47 in YS-98 and 8.98 in YS-16 at the planting distance of 25 cm. Maximum brix percentage was observed 13.17 in YS-98 and 15.06 in YS-16 at the planting distance of 25 cm (Table 4).

Table 4. Mean comparison for biochemical parameters

Biochemical parameters	**Variety**	**PS-1(10cm)**	**PS-2(15cm)**	**PS-3(20cm)**	**PS-4(25cm)**
Crude Protein	Variety 1	9.13	9.21	9.32	9.35
	Variety2	9.36	9.43	9.55	9.61
Crude Fiber	Variety 1	32.03	32.19	32.37	32.45
	Variety2	32.4	32.49	32.56	32.61
Ash %	Variety 1	8.12	8.23	8.4	8.47
	Variety2	8.71	8.21	8.91	8.98
Brix %	Variety 1	12.49	12.91	13.09	13.17
	Variety2	14.12	14.37	14.99	15.06

Plant spacing was highly significant for crude protein, crude fiber, ash (%) and brix (%)(Table 5).

Table 5. ANOVA for biochemical parameters

Biochemical parameters	***Variable***	***Mean Square***	***F- Value***
Crude Protein	Plant Spacing	0.06934	241.17**
	Variety	0.329	1144.36**
	P*V	0.00042	1.44 N.S
Crude Fiber	Plant Spacing	0.11897	632.48**
	Variety	0.39527	2101.42**
	P*V	0.01397	74.25**
Ash %	Plant Spacing	0.1176	440.03**
	Variety	1.7876	6688.59**
	P*V	0.00286	10.70**
Brix %	Plant Spacing	0.87	1212.74**
	Variety	17.87	24833.2**
	P*V	0.07	99.75**

*P*V=Plant Spacing vs Variety*

4. Conclusion

Standardization of agronomic procedures is always desirable for researchers to maintain optimum plant population at desired area. This allows even distribution of inputs among plants and minimizes drastic effects of competition between them. Maximum plant yield is obtained by maintaining optimum plant density. Productive potential of various sorghum cultivars are evaluated to investigate the influence of plant spacing on qualitative and quantitative plant traits.

The result of the present study shows that the sorghum variety YS-16 is performing better than the variety YS-98 in all parameters except in 1000 Grain Weight and panicle length. And in sense of plant spacing the observed data indicated that when the planting space was maintained at 25 cm optimum yield was obtained.

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